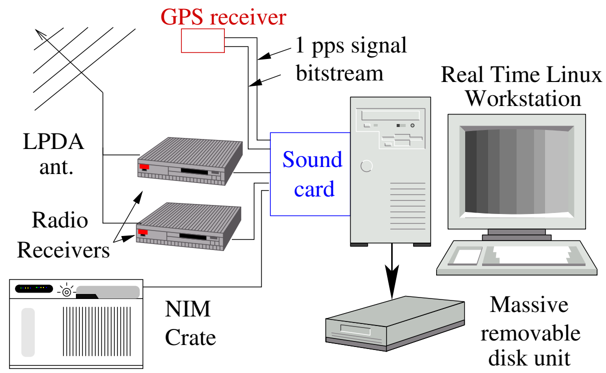


Figure 1. Radio Detector system with LPDA antennas, PCR-1000 radio and GPS receivers and a Real-Time Linux Workstation equipped with a Delta 1010LT sound card. See text for details.

# Improvements to the Cosmic Rays Radio Detector System

**Denis Oliveira Damazio & Helio Takai**
damazio@bnl.gov, takai@bnl.gov
Physics Department - Brookhaven National Laboratory.
Upton - NY. 11973

## 1. Introduction

High energy physics research relies primarily in accelerators. The highest energy achievable, 14 TeV, will become available around 2007 in proton-proton collisions at the LHC. Higher energies will require the construction of even larger facilities or new acceleration technology. One way to overcome the energy barrier at present is to use extreme energy cosmic rays (EECR) of energies larger than $10^{18}$ $eV$. At these energies, it has been suggested that even mini-black holes can be produced [1].

The main problem with this concept is flux. At rates of 1 event per square kilometer per year, extreme large detectors covering $10^6$ $km^2$ or more are required. In 2003, we initiated an effort to develop a proof of concept experiment to demonstrate that EECR can be detected by bi-static passive radars [4,5].

For the initial phase of the experiment we use signals from commercial broadcast TV stations as the main source of RF. The results shown at that time proved the clear sensitivity of the system to micro-meteors. Careful analysis, however, revealed problems with the recorded data. These were loss of samples and poor time resolution used in time stamping. Software redesign and a suitable operating system choice were made to solve the first problem. To solve the second problem we included the GPS bitstream in the data stream.

The signals used during the 2003 run of the experiment used RF from analog TV stations. The large number of stations in a relatively smaller range near to Brookhaven National Laboratory confuses the reception of stations below the horizon with the direct path signal. To reduce this problem, we decided to tune into digital TV (DTV) stations which are less numerous. The DTV stations have a pronounced carrier which is normally suppressed by analog TV stations. The detection of the reflected carrier is our main objective.

## 2. Experiment Description

In order to receive the reflected signals from the DTV stations, a Log-Periodic Dipole Array (LPDA) antenna was used. The antenna is characterized by large reception band (50-500 MHz in the model used) and a relatively directional pattern ($90^o$). The frequencies of the two DTV stations used are 54.309 and 66.309 MHz. The ICOM PCR-1000 radio receivers are tuned to these frequencies performing continuous wave (CW) detection with a 3 KHz band. The baseband signal is digitized by a Delta 1010-LT sound card[6] and read by a computer. See Figure 1 for details. The Delta 1010LT sound card can acquire signals at a very high sampling rates of up to 96 KHz. The acquisition of signals is performed at the maximum rate in order to detect the exact time and duration of the signal within the sampling precision.

The first version of the DAQ used an external time server. This approach suffers from network traffic and the precision of the computer clock. To produce results with a time precision only limited by the sound card, we decided to include the GPS reference signals directly in the data stream. The GPS time reference consists of 1 pulse per second (pps) and a NMEA bitstream which describes the conditions of the latest 1 pps signal (timing, position, number of satellites involved in the solution of both, etc) [9]. These are digitized as well by the sound card. The number of samples between pps signals is recorded within the radio data. The bitstream is recorded in a separated file for offline reconstruction of the NMEA bitstream.

In order to perform a comparison with a scintillating array, the coincidence signal from such array is also include in the data stream. This is to facilitate the search for possible candidates in the initial phase and applies for one array only.

Finally, to reduce the CPU usage letting it more dedicated to the data acquisition, no network access was allowed in the computer, while data is being acquired. To transfer data from the acquisition PC, a large (200 GByte) removable disk is used. After 3-4 days of acquisition, the disk is exchanged by an new disk ensuring a small loss of data.

## 3. Results

The new DAQ software was designed to be multithreaded, one thread for capture from the sound card and other for data displaying, handling and recording. The data acquisition thread must be designed to contain only one system call, the read function in the Unix C environment and must also be the highest priority thread in the system.

The operating system used was the GPL version of the real-time Linux (RTLinux[7]). To measure the percentage of data loss we counted the number of samples between two consecutive 1pps marks from the GPS. With the new DAQ no losses have been found after 5 days of continuous data acquisition.

We have also found out that hard disk performance to affect the overall data taking capabilities. The hard-disk performance was measured. Figure 2 show the performance for two different hard disks for different buffer sizes. The straight line shows the maximum time allowed for recording without loosing data when recording 8 channels at 96 KHz. Since the slope of this curve is higher than the very small slope of the hard disks, it is clear that increasing the buffer size is a good way of preventing data loss. The size of 8KBytes per channel was selected.

## 4. Conclusion

The radio detection data acquisition system has undergone a major upgrade with respect to its reliability. The GPS bitstream was added to the data stream providing an accurate time stamp for the data. A new run together with a scintillator array is under way and we will present on the most recent results in the conference.

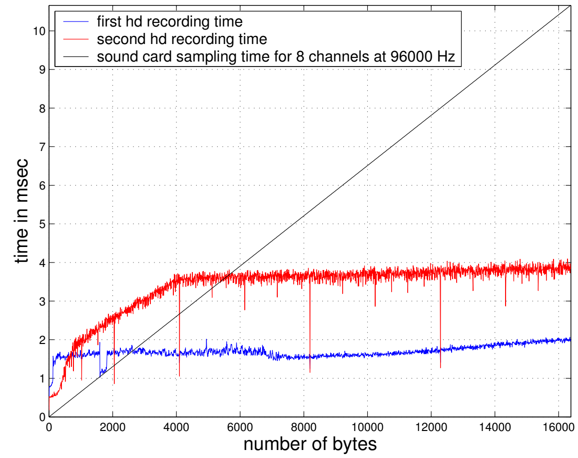


Figure 2. Measures using two different hard disks compared to the ideal time necessary to record 8 channels of data at 96KHz (straight line).

## REFERENCES

1. Feng, J.L., Shapere, A.D. "Black Hole Production by Cosmic Rays". *Phys. Rev. Let.* V. 88-2 (2002).
2. Hayashida *et al. Phys. Rev. Let.* V. 73. pp. 3491 (1994).
3. Dova, M.T. "Survey of the Pierre Auger Observatory". *Proceedings of ICRC* pp. 699 (2001).
4. Damazio, D., Takai, H., "A Radio Detector System for Ultra High Energy Cosmic Showers Study". IEEE Nuclear Science Symposium. Portland, U.S.A. (2003).
5. Damazio, D., Falcone, T., Mehta, N.L. and Takai, H., "A Simple and Cost-Effective Passive Radio Technique for Ultra High Energy Cosmic Ray Detection". Spacepart Conference. Washigton. U.S.A (2003).
6. http://www.midiman.net.
7. http://www.rtlinux.org.
8. http://www.deluo.com.
9. http://vancouver-webpages.com/peter/.